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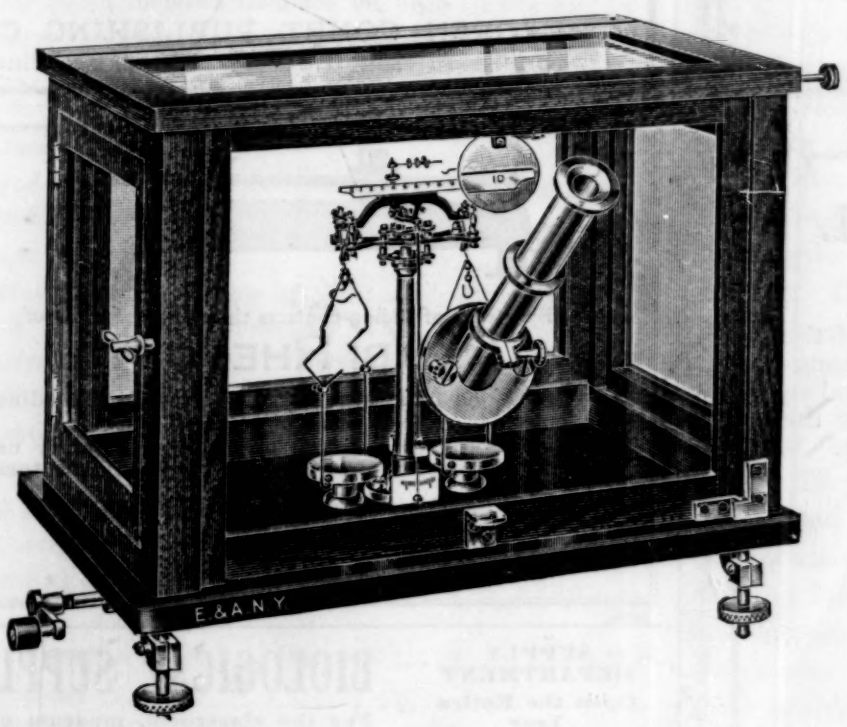

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THE SOLAR SYSTEM—SOME UNSOLVED PROBLEMS[1]

ABOUT forty years ago I attended several of the famous noon-hour lectures in Tremont Street Temple, Boston, by Dr. Joseph Cook. I should not be able now to quote anything Dr. Cook said, but I do recall distinctly that whatever his subject he did not at once begin to speak upon it, but gave first what he called a "prelude" upon some specially timely topic. With this distinguished precedent in mind, I venture to preface my address upon the unsolved problems relating to the solar system, by a plea for instruction in astronomy in our secondary schools.

This is a question to which I have given thought for many years, but the decision to speak about it to you to-night was formed as the result of a visit to the Lick Observatory in April by the senior class of one of our state teachers' colleges. I had the opportunity, in the course of the evening, to talk with several groups of these young people, who will, within a few months, be among the teachers to whom we entrust the education of our children.

Frankly, their ignorance of the most obvious of celestial phenomena and of the most elementary facts relating to the sun, the moon and the stars was appalling. Doubtless they all knew that the sun rises in the east, but I question whether they knew that this is also true of the new moon! Certainly, they did not know that the sun and the moon differ in size nor that the moon does not, like the sun, originate its light. They did not know the difference between a planet and a star, nor did they know even the most conspicuous of the stars and constellations. Orion and the Pleiades, Sirius and Arcturus meant nothing to them, so far as I could ascertain. I told them of the *teacher* to whom I once showed Jupiter, and who, after a single glance at the glorious disk, exclaimed "Is this a star? I thought all stars had five points!" and they looked at me with blank faces. Perhaps they, too, thought that Jupiter was a star and that all stars had five points!

If this were true of the students in only one institution it would be bad enough, but there would be no occasion for bringing the matter to your attention. Unfortunately, I fear that is true of a large proportion of the students in all our schools. It is entirely possible for a student to pass from the kindergarten

[1] Address of the retiring president of the Pacific Division, American Association for the Advancement of Science, delivered at Mills College, June 16, 1926.

to a university degree and remain as ignorant of these matters as the young people with whom I talked, and I fear that great numbers of them are in just that condition. I think it no exaggeration to say that the North American Indians in the days of Columbus knew more about the apparent motions of the sun, moon and planets, about the configurations of the stars, and the relation of their appearance in the night sky to the seasons of the year, than does the average university graduate to-day.

I am not concerned about the practical benefits of a knowledge of astronomy. I am not pleading that the technicalities of astronomy be taught to all our children. It is not necessary that they should be able to take a time observation, compute a comet orbit, observe the sun's altitude or find their way across country at night by the aid of the stars. Nor do I care to do more than mention the fact that it would seem hard to find better material for training the child's powers of observation than is afforded by the varying motions of the sun, the moon and the planets and the heliacal rising of the stars.

I do plead that every child has a right to be introduced to the stars as ever-present friends; to be taught the simple relations of the earth to the sun and moon and planets and stars; to have his imagination stimulated and his mental horizon widened by some conception of the vastness and the wonders of the greater universe.

Literature, from Job and Homer to Tennyson and Browning, abounds in allusions to the stars. What significance can they have to the teachers in training with whom I talked?

"What the Stars Predict," "Nannette's Horoscope," and similar puerilities are featured in our daily papers. Why not, when a large percentage of our people practically live in the Pre-Copernican age, so far as knowledge of the universe is concerned!

To free us from superstitions and the childishness of mind, of which a recent essayist complains; to give us a proper realization of relative human values; to teach us humility through knowledge of the insignificance of our puny earth among the worlds of space; and to help us to know exaltation through awareness that our earth and we ourselves are organic parts of this great universe; all this is the mission of astronomy. Is it not right to demand that every child in our schools be granted the opportunity to gain at least a little knowledge of this universe, "a universe," in the words of Justice Holmes, "not measured by our fears, a universe that has thought and more than thought inside of it!"

From the beginning of the present century astronomers have been giving their attention chiefly to the study of distinctively stellar problems; the number, distance and distribution of the stars, the motions of the stars, their organization into systems, the physical nature of stars and nebulae and their origin and evolution. In illustration of this tendency I may cite the fact that out of twenty-three papers to be presented at the meetings of the Astronomical Society of the Pacific to-morrow and Friday, only five relate to the solar system, and four of these have to deal with the sun. We are pressing our researches ever farther into space, and in recent years it is precisely the most distant known objects, the globular clusters and the spiral nebulae, that have contributed most strikingly to our knowledge. This is as it should be and is but the natural consequence of the development of spectroscopy and photography, the construction of giant telescopes, the development of ever more effective accessory equipment, and the great advance in knowledge of the fundamental properties of matter which have characterized this period. The additions that have been made to our knowledge of the greater universe within the lifetime of our own generation immeasurably exceed all that was known of it a hundred years ago.

The emphasis thus placed upon stellar research may lead the uninitiated to conclude that we have little or nothing more to learn about the motions or physical conditions of the bodies in our immediate solar system, and to correct that conclusion is one reason for my choice of subject. I am also of opinion that it is well, from time to time, to call attention to what we do *not* know, for I share in the view once expressed by the noted pathologist, Dr. Theobald Smith, that "to induce men to fill the gaps of our knowledge seems quite as important as the pioneering for entirely new vistas or outlooks."

Our knowledge of the general organization of the solar system may be said to be fairly complete. Nevertheless, wherever we turn, to sun, moon, planets or comets, we encounter unsolved and ofttimes apparently unsolvable problems. There are unexplained anomalies in the motions of the moon and of the planets; astronomical opinion is far from being unanimous as to the nature and origin of the surface markings on the moon, on Mars or on Jupiter; we know something about the rings of Saturn, but we do not know why Saturn and Saturn only has such rings; the origin and the mutual relations of the many hundreds of minor planets and of the even more numerous comets of long and short period are still open to question; we have some knowledge of *what* a sunspot is, but we do not know *why* it is; we can calculate the enormous amount of radiant energy emitted by the sun, in the thousand million years or more of its life history, and many recent brilliant investigations have convinced us that this store of energy is inherent. In

Eddington's words, it "is, with insignificant exception, energy of constitution of the atoms and electrons, that is to say, subatomic energy"; but as to the mechanism of its release and in particular, of the *constancy* of its release, we are still completely in the dark. We are convinced that the present form of our planetary system is the result of an orderly process of evolution, but we can give no account of its origin unless we assume the near approach of another star under conditions that amount almost to a special dispensation.

My enumeration is by no means exhaustive, but it lists some of the more obvious and important of the unsolved problems relating to our solar system and will serve to indicate how many are the gaps that still exist in our knowledge. Let us look more closely at some of these problems.

Celestial mechanics is justly regarded as one of the most exact of all the sciences. Its aim is to trace to the last detail the consequences of the law of gravitation as applied to the interaction of the various bodies in the solar system and to predict the future motions of these bodies. A dramatic illustration of the accuracy already attained was provided by the return of Halley's Comet in 1909, after its long journey out beyond the orbit of Neptune, in the course of which it had been invisible for nearly seventy-five years. The form of its orbit and the perturbations in its motion due to the attraction of the other bodies in the solar system were so accurately calculated that when the comet was found upon a photograph taken on September 11, 1909, its actual position upon the plate and the point predicted by the ephemeris for that date were separated by less than the breadth of a pinhead!

Nevertheless, there are unexplained anomalies in the motion of the moon and of the planets. The "Tables of the Motion of the Moon," published in 1919, by Professor E. W. Brown, of Yale University, are by far the most accurate so far constructed. The theory has been extended to include every known force that acts upon the moon, even in the slightest degree, and the equation expressing the moon's position at any date includes nearly one thousand five hundred terms, and yet Professor Brown writes in his preface:

> While many efforts have been made in the past to represent the motion of the Moon by gravitational theory alone, it is now admitted that this can not be done completely . . . There are oscillating differences (between observation and theory) which do not correspond to any theoretical gravitational terms, and they are large enough to exclude the possibility of being due to errors either in the theory or in the observations.

Following Newcomb, Brown has represented the principal portion of these by a purely empirical term, a term, that is, for which no explanation has as yet been accepted, with a period of about 270 years. Even then, puzzling oscillations of shorter periods and smaller amplitudes remain and, to quote again:

> All that can be done is to make an estimate of their magnitude from the observations of the past few years whenever it is desirable to predict the position of the Moon with high accuracy, as in the case of an eclipse of the Sun, and alter the values obtained from the Tables accordingly.

It is hardly necessary to say that astronomers are not willing to let the question rest here, even if, for practical purposes of observation, it is now possible at any time to secure a sufficiently accurate predicted position of the moon. We want an *explanation* of these differences which are not accounted for by known gravitational forces. The Einstein theory of relativity does not help us at all. In fact, this theory successfully accounts for but one of the outstanding anomalies in planetary motions—the advance in the perihelion of Mercury, and there are astronomers who are not yet convinced that it is necessary to invoke its aid in this instance.

Many years ago Newcomb pointed out that, "making abstraction of possible limitations imposed by the laws of motion, the observed fluctuations in the moon's mean motion may be equally due to actual changes in that motion or to changes in the earth's rotation, leading to errors in our measurements of time." At that time astronomers in general were not prepared to admit the possibility of variations in rate of rotation of the earth, and the hypothesis was not very seriously considered. Later attempts to account for the observed irregularities have, however, brought forward evidence which has placed Newcomb's suggestion in a more favorable light and within the past two months two quite different papers have appeared which argue strongly for its correctness. Dr. Innes, of the Union Observatory, South Africa, discusses the available observations of the transits of Mercury, and from them concludes that "the earth's rotation changes abruptly by an amount which is about ± 1 second a year"—and that "this change may continue until the total reaches about ± 30 seconds." "In compensation" for having to accept such an unwelcome conclusion, he adds, "this irregularity in one motion will more or less reconcile the motions of the moon, the satellites of Jupiter, the inner planets, and the sun."

Professor Brown, in his paper presented at the April meeting of the National Academy of Sciences, proceeding along different lines, also concludes that after all errors of observation are taken into account the remaining deviations in the moon's motion give good evidence in support of Newcomb's hypothesis.

He points out that the only reasonable explanation of such a variation in the earth's rotation time is one that assumes variations in the external radius of the earth, of from five inches to twelve feet, according to the depth of the source from which the changes originate, and considers the geophysical evidences of such oscillations. These are not wanting, and it is not at all impossible that they may be sufficient to produce the required effects. Further investigations along these lines and further observations of occultations of stars by the moon and of transits of Mercury are, however, required, before we can say that the problem is solved.

The moon, our satellite, is our nearest neighbor in space. Its mean distance is less than 240,000 miles, and even when it is farthest from the earth, light from it comes to us in less than one and a half seconds. It can be kept under almost continuous observation from every observatory in the world, and, moreover, it has no atmosphere and hence no clouds, and no dust storms to obscure our view of its surface. Every detail stands out sharply, and we can make accurate measures of positions and dimensions.

And yet astronomers are by no means in full accord in their views of the conditions upon the moon. The majority, I suppose, believe it to be an absolutely lifeless globe, upon which no change has been or is likely to be observed, however careful the survey and however powerful the telescope used. But there are not a few trained observers of great experience who are convinced that changes do take place, and that, particularly in or near certain of the craters, some of these changes are best explained by assuming the growth and decay of low forms of vegetation in the period of the lunar day. The water required to support such vegetation they assume to escape from the crater fissures. While I share the view of the majority on this question, I regard it desirable to settle it conclusively, if that is possible.

A similar statement may be made about the origin of the larger and smaller craters that pit the lunar surface. With the majority of astronomers, I hold that these have been produced by internal explosive forces, analogous to those to which we owe our volcanic eruptions. It must be admitted that it is difficult to account for all the observed details upon this theory, but it would seem to be still more difficult to account for them upon the only rival theory so far advanced with any plausibility, namely, that they are the consequences of a tremendous meteoric bombardment suffered in the early life of the moon. The latter theory, however, has strong adherents and the whole matter presents an interesting problem that may perhaps be solved conclusively by the new methods of investigation that are now available.

No one, so far as I know, has been able to suggest an explanation that is at all satisfactory for the bright streaks that radiate from several of the great craters like Tycho and Copernicus. They cast no shadows under any phase of illumination and hence can be neither elevations nor depressions on the surface, and they run without reference to topography, crossing craters, peaks and level areas alike.

Even the shape of the moon is not beyond question. Is it spherical, or is it ovoid, with the longer axis directed toward the earth, as might perhaps be expected to follow from the tidal interaction of the two bodies? It would seem possible to settle this point by a properly planned photographic investigation.

If the moon, which is so near us, and which offers us such continuous opportunity for observation, still presents so many unsolved problems, it is hardly reasonable to expect that our knowledge of our planetary neighbors should be complete, or even satisfactory. We do indeed know their mean distances from the sun, their masses, diameters and mean densities and some other statistical facts, within very narrow limits; beyond that, it is fair to say that we know comparatively little about them.

Our knowledge is most complete in the case of Mars. We know that it resembles the earth in having a solid crust, an atmosphere containing some water vapor, a succession of day and night almost precisely identical with our own and a succession of annual seasons that differ from our own chiefly in that each Martian season is nearly twice as long as the corresponding terrestrial one. Beyond this we know little. A definite advance was made at the opposition in 1924 in our knowledge of the temperature of the planet's surface, but much additional work is required before we can feel assurance on this point. Seasonal color changes have also been established beyond question, but whether the plausible conjecture that these are due to growth and decay of vegetation is the best explanation is still not beyond dispute. While all observers agree that the amount of water on the planet's surface is very limited, observations made in 1924 throw some doubt upon the conclusion generally accepted before that time that the Martian atmosphere is not only rare, but very limited. As to the nature of the famous system of canals, or by whatever other name we designate the markings on the planet's surface, the views of astronomers are as divergent to-day as they were a generation ago. Views as to the habitability of the planet vary with the opinions held on these disputed points. Some advance in knowledge may be expected from the observations to be made at the approaching opposition of Mars. Photographic studies, in light of different wave lengths, checked by comparative photographs of other objects, should lead to a better deter-

mination of the quality and extent of the planet's atmosphere, and radiometric measures should yield more accurate values of the temperature.

In my college course in descriptive astronomy, I learned that Jupiter and Saturn were bodies more closely resembling the sun than the earth in physical conditions; that is, that they were wholly gaseous, and still intensely hot; these conclusions resting chiefly upon their known low mean densities. Now, radiometric observations indicate that their surface temperatures, at least, are extremely low, so low as to make improbable any heat supply aside from solar radiation. That reopens the whole question as to the physical condition of these planets, and as to the nature of the complicated and ever-varying system of markings which produce the appearance of the characteristic and beautiful belts. The variation in the rotation periods of these planets with the latitude, like the similar variation in the rotation period of the sun, raises another question for which we have no positive answer.

Moon and planets shine only by reflected sunlight and their spectra should therefore be identical with the spectrum of the sun, except as the light is affected by passing through the atmosphere of the planet or of the moon. The spectra of the moon, of Mercury and of Venus, in point of fact, show no atmospheric absorption effects. It is doubtful whether or not such effect is visible in the spectrum of Mars. A few astronomers consider that it shows evidence of the presence of water vapor in the Martian atmosphere, but the majority regard this evidence as of very little weight.

The case is different for the four outer planets. The spectra of Jupiter, Saturn, Uranus and Neptune are characterized by broad absorption bands in the less refrangible or red end of the spectrum. Doubtless these bands will tell us much of the nature of the atmosphere—or outer layers of these planets, if we regard them as gaseous throughout—when we have learned to interpret them. The message has been written and has been delivered to us, but so far we have been able to read but a very small fragment of it.

And why has Saturn, and Saturn only, that beautiful ring system? It has been known since the time of Clerk Maxwell that the rings consist of an innumerable assemblage of fragmentary bodies; and the spectrographic measures by Keeler proved beyond question that these bodies in each successive zone of the rings are revolving about the planet in a period appropriate to a satellite at that distance from its center. But while we know their nature and can measure their breadth and thickness, no one has, so far as I am aware, ever suggested even a plausible hypothesis for the existence of the rings. They seem to be absolutely unique; the only system in the least resembling them being the ring of asteroids or minor planets between Mars and Jupiter, and the resemblance here is remote indeed. The asteroid belt contains more than a thousand known, and probably thousands of unknown tiny bodies. These are quite numerous at certain average distances and are few, or lacking, at certain intermediate distances, giving the effect of vacant lanes vaguely analogous to Cassini's Division between the two bright rings of Saturn. The minor planets resemble the Saturnian Ring System also in the fact that no one has yet advanced any adequate theory for their existence and particularly for their existence in the general region where, since Kepler's time, it seemed reasonable to expect to find another planet.

It was this expectation and the cooperative search for such a planet, based upon the relation between the mean distances from the sun of the known planets which has been formulated in what is known as Bode's Law, that led to the discovery of the first few minor planets. It led also to the hypothesis, when the number of known objects had increased, that these bodies were the remnants of a shattered planet. The hypothesis is now quite untenable, but we have no really satisfactory substitute.

The care of the known minor planets, their observation and especially the computation of their "perturbations" constitute a practical problem of the first magnitude. They number, as has been said, more than one thousand, in fact, more nearly one thousand one hundred, and additional discoveries are being made yearly. Their orbits are in many instances considerably more eccentric than those of the planets, the inclinations of their orbit planes show a far greater range, and in their orbital motions about the sun they are all greatly affected by the disturbing attractions of their planet neighbors, particularly Jupiter. These perturbations, in some instances, change the orbit so radically that when the minor planet is again observed it may be mistaken for a new body.

Work of great value in the way of computation of perturbations and the preparation of tables of a number of the more interesting asteroids has been done at several different institutions in our own country and abroad. But the task of carrying out the necessary observations and computations for all these bodies far exceeds the powers of any single institution. A well-planned cooperative program of research is needed, and it is to be hoped that the efforts now being made to effect this, under the auspices of the appropriate committee of the International Astronomical Union, may be successful.

The relations of the minor planets to other bodies

in the solar system raise some interesting questions. For years it appeared that they all revolved about the sun between Mars and Jupiter. More recently a number have been discovered whose aphelia lie beyond the orbit of Jupiter, and a smaller number which at perihelion come well within the orbit of Mars, and approach the earth more nearly than any body except the moon and an occasional comet. In passing, it may be noted that these latter planets are admirably adapted for precise determinations of the solar parallax, and the best known member of the group, Eros, was in fact extensively observed for that purpose at the favorable opposition of 1900. Another very favorable opposition occurs in the winter of 1930–1931, and plans are already maturing for a similar campaign at that time.

It is not at all improbable that other small bodies may be found which differ in no particular from the known minor planets, except that the outer ends or aphelia of their orbits lie farther from the sun, as far out as the orbit of Saturn, or even farther. The question then arises, may not an occasional wanderer of this kind be "captured" by Jupiter or by Saturn and be forced thereafter to revolve as a satellite about one or the other planet? In point of fact, when the eighth satellite of Jupiter was discovered at Greenwich, it was uncertain, at first, whether it was a satellite or a minor planet. This satellite and the ninth, discovered at the Lick Observatory, describe their orbits in what is known as the "retrograde" direction, whereas the other seven satellites, like almost all the other satellites and planets in the solar system, move in direct orbits. This does not necessarily preclude the capture theory of their origin. Greater stability is obtained by retrograde than by direct motion at the great distance of these satellites from their primary and that may permit those forced into retrograde motion at time of capture to survive, while others are recaptured by the sun. This is speculation, of course.

There is another group of objects which revolve about the sun in quite eccentric orbits whose aphelia lie near the orbit of Jupiter, while their perihelia lie within the orbit of Mars, or even of the earth. This group is known as the Jupiter family of comets. These comets are all apparently small bodies, consisting of a more or less sharply defined nucleus, surrounded by a nebulous envelope or coma. The tail, which is the most prominent feature of a comet as usually depicted, is entirely lacking, and in some instances the nucleus is so sharp and the coma so faint that the object is hardly distinguishable from an asteroid. If no other comets were known there can be little question but that we should class these objects with the asteroids, noting the nebular appearance as an individual peculiarity to be accounted for, just as we now note the variability in brightness of certain of the asteroids, and it is not impossible that there is a real relationship between the two groups of objects.

The general opinion, however, is that these comets originally revolved in orbits of much longer period and much greater eccentricity and that they were drawn into their present orbits by the powerful perturbing action of the planet Jupiter. In similar manner it is suggested that Halley's Comet owes its present orbit to the attraction of the planets, chiefly Neptune.

We know that comets exist in the outer regions of the sun's domain in very great numbers. The orbits they describe, while far distant from the sun, are very elongated ellipses of such dimensions that their revolution periods must in general be reckoned in thousands of years. They are only visible to us for a short time during which they are near their perihelion points and then they seem to describe arcs of the open curves, known as parabolas or hyperbolas. This, and the fact that their orbit planes are inclined at all possible angles, led to the theory that such comets, which include nearly all the brilliant ones that have been observed, are visitors to our system from external space. In his address on "What we know of Comets" delivered to the Pacific Division at the San Diego meeting ten years ago, Dr. Campbell summarized the researches of various astronomers which have established the fact that these apparent parabolic or hyperbolic orbits are due to planetary perturbations and that before they came under these disturbing influences all these comets were travelling in elliptic orbits. The evidence is conclusive that the "parabolic" comets as well as the short period comets originated in the solar system.

Dr. Campbell lends the weight of his personal opinion to the view that not only the long period "parabolic" comets but also comets like the one that bears Halley's name and those of the Jupiter family consist of fragments from the outer portions of the primal nebula or stream of matter out of which our planetary system developed, though he adds that this view is to a certain extent speculative. This would imply that the periodic comets owe their present orbits to relatively close encounters with one or more of the major planets. Dr. Crommelin, the well-known English authority, has recently questioned the validity of the latter conclusion, largely on statistical grounds. To effect the radical change in orbit demanded to bring it into the Jupiter family, a comet, according to his calculations, would have to pass Jupiter at a distance less than that of its fourth satellite and only one comet in five hundred thousand would pass the planet

within this distance. On the average, he concludes, it would require two hundred thousand years for Jupiter to capture a comet, and, at this rate, it would be difficult indeed to account for the more than forty members of the family. A fact of importance in this connection is that these short-period comets are apparently also relatively short-lived, and one or two have been lost completely within quite recent times. Their substance is wasted away or scattered all along their orbit by the disintegrating influence of the sun. The earth periodically encounters swarms of meteors, the Perseids, for example, and in some instances, at least, it is practically certain that these meteors are the fragmentary remains of comets.

Whatever may be the truth in the matter, it is evident that we have still quite as much to learn about these minor members of the solar system as about the planets themselves.

Most important of all, however, are the unsolved problems relating to the sun itself, partly because it is but a slight exaggeration to say that the sun *is* the solar system, since it contains within itself 99 6/7 per cent. of the mass of the system; partly because what happens upon the sun must always be of paramount interest to us dwellers upon the earth, since our very lives depend upon the energy it radiates. From the astronomer's viewpoint there is the additional reason that the sun is a typical star which is believed to have passed the meridian of its course and to be now on the dwarf or descending branch of its evolutionary curve. A complete solution of solar problems is equivalent to the solution of one of the two major problems of astronomy, the problem of stellar evolution. That is why observatories have been and are being established in different parts of the world equipped with apparatus designed to study every detail of the solar surface and to measure with greatest accuracy the intensity of the solar radiation. That is why it is worth while to spend time and labor and money on expeditions to distant parts of the earth to observe total eclipses of the sun, which provide our only opportunity to study the outer atmosphere of the sun, the corona. That is why, to refer to just one detail, we are so eager to know all about sunspots. Why do they appear at all; why does their number vary periodically; why in each cycle do they appear first in moderately high latitudes, 30° to 40° (but never at or near the poles), and then in increasing numbers in lower latitudes, leaving, however, a nearly free zone of about 10° on either side of the equator; and why is the polarity of the magnetic sunspot fields reversed in the alternate eleven-year cycles? We have made remarkable advances in our knowledge of all solar phenomena in the last few decades, through the researches at such observatories as those on Mount Wilson and at Meudon, Paris, to name but two of many, but our answers to the questions I have enumerated and to many others must still be regarded as more or less plausible speculations.

This is particularly true of the two most fundamental problems of all: what is the source of the sun's heat, and what is the nature of the mechanism by which it is generated at just the rate required to keep its radiation practically constant through hundreds of millions of years?

Consider the magnitude of the problem. According to Abbot and Fowle the solar constant is 1.93 calories. That means that every acre of the earth's surface which is exposed to the vertical rays of the sun is constantly receiving energy at the rate of four thousand horse power. But as seen from the sun, the earth's disk would cover only one two billionth part of the surface of the celestial sphere. Therefore, if we make the natural and plausible assumption that the sun is radiating light and heat with substantially equal intensity in all directions, the heat radiated into space by the sun must be two billion times that intercepted by our earth. In other words, the sun must be continuously radiating energy at the rate of approximately a million million million million (10^{24}) horse power.

No geologist is prepared to accept a figure short of two hundred to two hundred and fifty millions of years for the age of the earth; the majority demand an age at least three times as great; and geological evidence strongly supports the contention that throughout this enormous stretch of time the radiation received from the sun has not varied in any marked degree. Even the glacial epochs may be accounted for, not by variations of the sun's output of heat, but by changes in the conditions governing its transmission to the earth's surface; possibly by the passage of our solar system through one or more of the great gaseous nebulae which are known to abound in that part of the stellar system away from which we are now travelling.

Cosmogonists are as insistent as geologists in their claims for the great age of the sun and of the stars. Jeans says that "the figure of 10^9 (*i.e.*, a thousand million) years is the absolute minimum that can be considered" for the age of the sun, and Eddington, "certainly we can not abate our demands below 10^9 years." The actual figure, both believe, is vastly greater.

What is true of the sun must be true also of every one of the stars in our system, with due regard to individual differences in mass and in temperature, and to estimate the number of the stars at one thousand five hundred million is to be very conservative. Quite recently I have seen the number seriously set down

as ten billion. We can write the figures which represent the total energy radiated into space by all these millions of stars continuously through a thousand or ten thousand million years, but who can comprehend their significence?

What is the source of all this energy? One statement about it, at least, may be made with confidence; it must lie deep within the sun (or star) itself; for, as Eddington remarks, supplies of energy from without, from whatever source, would simply affect the surface temperature and increase for the time being the intensity of the radiation emitted. They would not prolong the life of the sun at all. That is why the Helmholtz-Kelvin contraction hypothesis was at first received so favorably. This theory assumes that the gravitational energy released by the sun's gradual contraction suffices to balance the heat radiation, and it can, in fact, be shown that the sun's present radiation would be accounted for by a shrinkage in diameter too small to be measurable in a period of less than five thousand years. There is no question but that gravitational contraction does operate to generate heat in the sun, but, on the most favorable assumption, if this were the only source of solar energy, the sun's past life would be limited to about forty-six million years. The hypothesis is thus hopelessly inadequate. Nor does the suggestion of radioactive forces, though they too must contribute, give much help, for at best they can add but a few million years to the sun's life.

The one adequate source seems to be found in the very constitution of matter itself under the conditions of temperature and pressure prevailing in the deep interior of the sun or of a star. Under modern theories, which have been discussed in detail in the symposium this afternoon,[2] a rapidly moving electron has greater mass than one at rest, "since more force is required to deflect it from its path or to produce a specified acceleration." It follows that any body which receives energy increases its mass and one which radiates energy loses mass. The sun, on this basis, by its radiation is losing mass at the enormous rate of four million tons a second or more than one hundred and twenty million million tons a year. Even at this prodigious rate it would lose but one tenth of one per cent. of its mass in fifteen thousand million years. The theory thus solves, as Jeans says, "with a comfortable margin to spare the age-long problem of the source of the energy of stellar radiation."

But it does not by any means relieve us of our difficulties, for we have still to account for the mechanism of the release of energy, or the conversion of matter, in our usual definition of the term, into energy, and for its release at just the rate required to maintain the constant radiation from sun and stars. So far all attempts to solve this problem have raised more difficulties than they have cleared away, and Eddington, whose name is intimately associated with such progress as has been made in its investigation, is forced to conclude his most recent series of lectures on "the source of stellar energy" with the paragraph:

> I should have liked to close this course by leading up to some great climax. But perhaps it is more in accordance with the conditions of scientific progress that it should fizzle out, ending with a glimpse of the obscurity which marks the frontiers of present knowledge. I do not apologize for the lameness of my conclusion, for it is not a conclusion. I wish I could feel confident that it is even a beginning.

Eddington's words are not words of discouragement. Rather, they are a stimulus to more strenuous efforts. There is so much still to be learned, there are so many problems still to be solved. We need more data, data secured by the execution of carefully planned programs of observation and experiment. Data relating to stars and nebulae, but also data relating to the moon, the planets, the asteroids and the comets of our own solar system. They all hold secrets, secrets which can be unveiled, and in Professor Whitehead's words, "it is this instinctive conviction vividly poised before the imagination, which is the motive power of research."

ROBERT G. AITKEN
LICK OBSERVATORY

[2] June 16, 1926.

SCIENTIFIC EVENTS

RECENT RESEARCHES AT THE NATIONAL PHYSICAL LABORATORY OF GREAT BRITAIN

A LARGE number of visitors were given an opportunity of seeing something of the work of the National Physical Laboratory at Teddington on the occasion of the annual inspection by the general board. According to the London *Times*, the exhibits—nearly 200 were enumerated in the program—were for the most part selected to illustrate the more recent researches undertaken by the laboratory and the methods and apparatus employed in carrying them out.

Perhaps from the point of view of mere size the equipment of the aerodynamics department and of the ship-model experiment tank is the most imposing of all. In the former the whirling arm, one of the older pieces of apparatus, has been reconstructed and is to be used for experiments on aeroplane and airship models to determine the effect of a steady rotation in yaw upon the aerodynamic forces and moments. The shed in which it is housed has been made

octagonal instead of square by placing screens across the corners. A new one-foot wind tunnel, which provides wind speeds up to 140 feet per minute, is primarily intended for the development and calibration of instruments for measuring the speed and direction of the wind. In the duplex wind tunnel experiments are being made on a model of the Cierva autogyro, and in one of the seven-foot tunnels the conditions of the spinning of aeroplanes are being studied.

Other investigations in progress relate to high-lift wings of the Handley-Page slotted type, and to the dissipation of heat from the surfaces of wings in a wind current, the latter inquiry being in connection with the plan of enclosing the radiators of water-cooled engines in the wings with the object of reducing head resistance in high-speed aeroplanes. In the Froude tank visitors saw experiments with a self-propelled single-screw steamer, the apparatus used for measuring its speed, screw thrust, revolutions of propeller and power required for propulsion being demonstrated.

In the metallurgy department exhibits were on view illustrating the work done on light alloys, particularly of magnesium, of aluminium and silicon, and of aluminium, silicon and copper, and also on alloys for use at high temperatures. The melting of the latter is now effected in electrical high-frequency induction furnaces, gas-fired crucible furnaces having been found unsatisfactory owing to contamination of the product by oxide. For these and other investigations metals free from impurity are necessary, and there were exhibits showing what has been done in the production of chromium, manganese, iron, beryllium and silicon as nearly pure as possible, as well as in the preparation of special refractory materials for making the pots and crucibles employed in melting them. Another research which is of interest in connection with the amalgams used by dentists for stopping teeth consists in the microscopic examination of metals and alloys that are liquid, or partially liquid, at atmospheric temperatures, by polishing and etching them while they are frozen solid.

In some of these metallurgical investigations the engineering department is taking a share. It is concerned, for instance, in determining the mechanical properties of alloys intended for use at high temperatures, and another example of joint action is the research on the embrittlement of iron chains, such as are used for cranes, and the effect of heat treatment. But it has much work of its own on hand, and among other things it showed testing machines of various kinds, as for gear-boxes, spur gears, laminated springs and big-end bearings; apparatus for recording the vibrations of the ground caused by traffic; shadowgraphs of air jets from nozzles of different forms and hardness tests made with diamond cones.

Besides exhibiting mercury vapor vacuum pumps made entirely of metal, the physics department illustrated the determination of the heat conductivity of metals and other substances; the photography of sound waves and the measurement of the intensity of sound and of its transmission and reflection by partitions; and the X-ray examinations of metals and X-ray spectrometry. The new vector colorimeter was on view in the Optics Building, and methods of measuring daylight in the open and daylight illumination in various types of rooms were shown in the Illumination Building. In the main wireless hut in the meadow there was a sensitive direction finder for long waves up to 20,000 meters, and experimental transmitting and receiving apparatus for short waves down to 20 meters. Extensive displays of apparatus were also made by the electrotechnics and metrology departments.

INDIAN MOUNDS IN LOUISIANA

DEFINITE addition to knowledge of the prehistoric Indian life of this continent has been made by Mr. Henry B. Collins, Jr., of the Smithsonian Institution, in the discovery of large mounds on the marshy coast of Louisiana, west and south of New Orleans. Hitherto, it had been supposed that the Attacopa Tribe of cannibals had been the only inhabitants of the western part of the area.

Mounds found by Mr. Collins, one of which rises 45 feet above the level of the surrounding country, indicate the presence of a highly developed people. Mr. Collins believes it possible that the builders of the newly discovered mounds were the ancestors of the Chitimacha Indians, a cultured people who are known to have occupied an adjoining territory.

In his excavations Mr. Collins discovered several fireplaces six feet below the surface of one mound, indicating that the mound had had two stages of development. The majority of the mounds were probably used for temple sites and the residences of priests and chiefs. Sometimes burials took place in them. Mr. Collins brought back a series of skulls of these mound builders which will be studied to determine their racial affinities. The pottery relics which he found reveal the same type of ornamentation as that common to the Gulf region eastward to Florida.

MUSEUM OF THE PEACEFUL ARTS

DR. GEORGE F. KUNZ has announced that the projected Museum of the Peaceful Arts in New York City will soon be realized. A site on city-owned ground in upper Manhattan is under consideration by the trustees and exhibits are being collected.

Henry R. Towne, who died in 1925, left $2,500,000 to found the museum and $50,000 for preliminary study. This latter money is now being utilized. In addition the trustees have received nearly $200,000 interest on the bequest.

Actual work on the enterprise began in 1908, when the Association for the Establishment and Maintenance in the City of New York of Museums of the Peaceful Arts was incorporated. The officers are: Dr. George F. Kunz, *president;* Elbert H. Gary and Frank D. Waterman, *vice-presidents;* Calvin W. Rice, *secretary;* Felix M. Warburg, *treasurer.* Honorary vice-presidents are: Thomas A. Edison, Sarah Cooper Hewitt and Melville E. Stone.

The Towne bequest will be available as soon as the museum association satisfies the heirs that the preliminary research and surveys of similar museums in England, France, Germany, Denmark, Norway, Sweden, Austria and other countries have been completed.

Dr. John W. Lieb, vice-president of the New York Edison Company and one of the trustees of the association, is now in Europe on a survey of industrial museums. He will report to the trustees next month. Among the exhibits planned will be sections on electricity, steam, astronomy and navigation, safety appliances, aviation, mechanical arts, agriculture, mining, efficiency, historic records, health and hygiene, textiles, labor, ceramics and clays, architecture, scenic embellishments, gardening, roads and road-building materials, commerce and trade, printing and books, patent models and patents, transportation, pottery, gems and minerals, watchmaking, and hundreds of other lines of industrial endeavor, arts and crafts.

The museum will cover the entire history of man from the earliest time in his effort to subdue nature. The following exhibit offers have been received: A collection of carriages of the eighteenth and nineteenth centuries from Miss Sarah Cooper Hewitt; an ancient potter's wheel from Ambrose Swasey, one of the trustees; a collection of ancient sundials and astrolabes, an ancient timepiece and a collection of watch movements from the Horological Institute of America.

THE PAN-PACIFIC BOTANIC GARDEN

IT is planned to establish a Pan-Pacific Botanic Garden in Hawaii. The plans for such a garden are developing in three directions:

First, a collection of economic trees and plants from every Pacific land will be brought to Hawaii and planted at various suitable elevations on the different islands from sea level up to some twelve thousand feet above the ocean, according to the climatic habitat of the introduced plant. This part of the plan is well under way with numerous offers of cooperation from men of means who own available areas at the needed elevations on the several islands of the Hawaiian group. These land owners have abundant manual labor to tend and cultivate the trees and plants committed to their care.

The second plan is, in addition to the first, to secure a suitable valley, where from the ocean to the mountain top introduced trees may be planted, cared for and studied. The Plant Constituent Council of the Pan-Pacific Research Institution is interested in this, as it would make materials for research available for the laboratory. It is proposed, if possible, to secure a well-watered valley in which there is a worth-while growth of indigenous trees, which would be added to from the other islands, the areas of the valley not covered with native forests being used for introduced trees and plants.

The third part of the plan contemplates a show garden in the city of Honolulu, to which from time to time the plants and trees of interest to the casual visitor may be exhibited. This garden will be used for propaganda work.

The following is the personnel in Honolulu of the Pan-Pacific Botanic Council of the institute. A larger advisory group will be added and an effort will be made to establish similar councils in each Pacific land, with kindred aims and an exchange of plants and knowledge:

Willis T. Pope, horticulturist, U. S. Agricultural Experiment Station, *chairman.*

C. S. Judd, director, Territorial Board of Agriculture and Forestry.

Professor F. C. Newcombe, botanist, president of the Hawaiian Academy of Science.

Forrest B. Brown, botanist, Bishop Museum.

E. M. Ehrhorn, director, Plant Quarantine Station.

Solomon Kekipi, Hawaiian botanist.

David Haughs, nurseryman, Territorial Board of Agriculture and Forestry.

W. O. Smith, Hawaiian Sugar Planters' Association.

J. M. Westgate, director, U. S. Agricultural Experiment Station.

Dr. Wm. D. Baldwin, horticulturist, Maui.

Gerrit P. Wilder, botanist, Bishop Museum.

Wilbur J. McNeil, chemist and general scientist, Oahu College.

THE RETIREMENT OF UNIVERSITY PROFESSORS IN GERMANY

A CORRESPONDENT of the *Journal* of the American Medical Association writes: "As a result of the provision contained in the new federal constitution to the effect that government officials, clerks and employees must be pensioned at the age of 68, at the latest, many head professors of the medical faculties,

who had reached the age limit, have been retired. Professors who had not felt that they needed to be pensioned as yet have complained bitterly of their enforced retirement. It may be that many of these were perfectly able to carry on for some time longer, but, in general, when the age of 68 has been reached it is time for younger men to take the helm. In Germany, enforced retirement on attaining a certain age is all the more justified for two reasons: (1) During the war many professors aged more rapidly than normally, and (2) during the war fewer promotions were made, and there is consequently a larger number in the oncoming generation awaiting openings. One thing that makes the pensioning of head professors more endurable is the fact that it affects only the management of institutes, clinics and the like. Otherwise, pensioned professors are entitled to continue holding their lectures; they remain members of the faculty and receive also the entire salary and lecture fees that they collect from students. During recent years, the aforementioned retirement regulation has brought about many changes in the medical faculty at Berlin and elsewhere.

"At the University of Berlin the following head professors of the medical faculty have been retired: Rubner, the physiologist, and Hans Virchow, the anatomist. At the end of this semester, F. Kraus and Goldscheider (internal medicine clinics); F. Strassmann, legal medicine, and Williger, dentistry, will be pensioned. As the post left vacant by the death of Hofmann, physiologist, must be filled, and an occupant for the chair of pharmacology must be found, there are six professorships awaiting new incumbents. It is the general opinion that Kraus will probably be succeeded by his former pupil von Bergmann, of Frankfort-on-the-Main, the son of the famous surgeon, now deceased. As to the successor of Goldscheider, the outcome is not as yet certain. One prominent candidate is Professor Umber, director of the Charlottenburg Municipal Hospital, who has made a name for himself in the field of diseases of metabolism—more particularly by his excellent text-book."

In addition to the men in the medical sciences listed in the *Journal*, the retirement is announced of Dr. Max Planck, professor of physics in the University of Berlin; of Dr. Eugen Korschelt, professor of zoology in the University of Marburg, and of Dr. Wilhelm Wedding, professor of electrotechnics at the Berlin Technical Institute.

SCIENTIFIC NOTES AND NEWS

AT the recent meeting of the British Association for the Advancement of Science, the University of Oxford conferred the honorary degree of doctor of science on the following men of science: Dr. Niels Bohr, professor of physics in the University of Copenhagen; Sir Frank Watson Dyson, astronomer royal; Dr. Arthur Stanley Eddington, Plumian professor of astronomy at the University of Cambridge; Sir Daniel Hall, chief scientific adviser to the British Ministry of Agriculture; Dr. Henry Fairfield Osborn, director of the American Museum of Natural History; Dr. Vita Volterra, professor of mathematics at the University of Rome, and Professor Wilhelm Wien, professor of experimental physics at the University of Munich.

AT the Oxford meeting, Dr. Henry F. Osborn gave one of the principal lectures on "The Methods and Results of the American Museum Expeditions in the Gobi Desert," and an address before the section of zoology on "The Problem of the Origin of Species as it appeared to Darwin in 1859 and as it appears to us To-day."

OTHER American men of science who expected to attend the Oxford meeting of the British Association are: Dr. George D. Birkhoff, professor of mathematics at Harvard University; Dr. Douglas H. Campbell, professor emeritus of botany of Stanford University; Dr. Frank Wigglesworth Clarke, chief chemist of the U. S. Geological Survey; Professor Edwin G. Conklin, professor of zoology at Princeton University; Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology; Dr. F. L. Stevens, professor of plant pathology at the University of North Carolina; Professor Henry B. Ward, professor of zoology in the University of Illinois; Dr. Vernon Kellogg, secretary of the National Research Council, and Dr. William McDougall, professor of psychology at Harvard University.

THE Eighth International Congress of Psychology meets at Groningen, Holland, from September 6 to 11. The American psychologists on the program include Professor Edwin G. Boring, Professor William McDougall and Professor Daniel Starch, of Harvard University; Professor James H. Leuba, of Bryn Mawr College; Professor Herbert S. Langfeld, of Princeton University, and Dr. L. J. O'Rourke, of the U. S. Civil Service Commission.

THE forty-ninth anniversary of the invention of the phonograph in 1877 by Thomas A. Edison was observed on August 12 by appropriate ceremonies at the Edison Laboratories in West Orange, N. J. Mr. Edison was greeted by more than a hundred members of the sales force of the Edison organization from all parts of the United States and Canada.

DR. SIMON FLEXNER, director of the Rockefeller

Institute for Medical Research, has been elected a corresponding member of the Sociedad Médico-Quirúrgica del Guayas, of Guayaquil, Ecuador.

THE Terry lectures for 1926–27 will be given at Yale University by Professor Robert A. Millikan, Ph.D., of the California Institute of Technology, on October 13, 14 and 15, and repeated in Bridgeport on October 17, 18 and 19. Other lecturers on this foundation have been J. Arthur Thomson, author of the "Outline of Science"; Professor Henry N. Russell, of Princeton University, and Professor William Ernest Hocking, of Harvard University.

PROFESSOR VON EISELSBERG, of Vienna, who last June was awarded the Lister Medal of the Royal College of Surgeons, London, for distinguished contributions to surgical science, with an honorarium of $500, has undertaken to give an address at the Royal College of Surgeons on July 7, 1927.

THE honorary degree of D.Sc. of the University of Wales has been conferred on Sir T. W. Edgworth David, professor of geology in the University of Sydney, and on Dr. A. H. Church, lecturer in botany at the University of Oxford.

IN observance of the completion of his thirty years as a member of the faculty of Cornell University, the graduate students of Dr. Benjamin Freeman Kingsbury, Ph.D., '95, presented to the university on June 10 a portrait painted by Professor Olaf M. Brauner. Professor James G. Needham, '89, presiding at the gathering of friends and former students of Dr. Kingsbury, introduced Dr. Frederick W. Stewart, '16, who, in behalf of the graduate students, gave the presentation address. After the unveiling of the portrait by Dr. Kingsbury's daughter, Dean William A. Hammond accepted it for the university. The presentation of the portrait in the afternoon was followed in the evening by a banquet in honor of Dr. Kingsbury, presided over by Professor Needham. Professor Simon H. Gage and Professor Pierre A. Fish were among the speakers.

FORMER students of Dr. L. R. Jones, professor of plant pathology at the University of Wisconsin, presented to the university an oil painting of their teacher at the International Congress of Plant Pathology at Cornell University on August 19. The group of donors includes men and women who have studied under Professor Jones at Wisconsin and also at the University of Vermont where he taught and conducted research before coming to Wisconsin. Their intention is to commemorate his contribution to the knowledge of plant pathology and his successful conduct of graduate work in that field. The portrait will hang in Agricultural Hall with those of other members of the university who have made outstanding contributions to knowledge.

ASSOCIATES and friends of Professor V. A. C. Henmon, who has resigned the directorship of the school of education at the University of Wisconsin to become research professor in educational psychology at Yale University, recently gave him a dinner sponsored by Phi Delta Kappa, the honorary educational fraternity. Professor M. V. O'Shea, the oldest member of the faculty of the department of education, and Professor F. D. Cheydleur, of the department of Romance languages, expressed the appreciation of Professor Henmon's colleagues for his direction of the work in education.

THE title of emeritus professor of electrical engineering in the University of London has been conferred on Professor J. A. Fleming, on his retirement from the chair of electrical engineering at University College.

WE learn from *Nature* that on July 8, on the occasion of his retirement from the Bayer chair of zoology in Manchester University, Professor Sydney J. Hickson was presented with a check by Sir William Boyd Dawkins, on behalf of a number of his former students, colleagues and friends. Sir William Boyd Dawkins, the principal, referred to Professor Hickson's services to science, to the work which he has done for the university, and for the cause of education in natural science. A dinner has been arranged in Professor Hickson's honor at the University Refectory on October 29.

PROFESSOR WILLIAM J. MILLER, chairman of the department of geology in the University of California, Southern Branch, Los Angeles, was given the honorary degree of doctor of science by the College of the Pacific at its diamond jubilee commencement.

THE following are the newly elected officers of the American Society of Plant Physiologists: *President,* F. E. Lloyd, McGill University; *Vice-President,* Wright A. Gardner, Alabama Polytechnic Institute; *Secretary-Treasurer,* Scott V. Eaton, University of Chicago.

THE officers of the Alabama Academy of Science for the current year are: *President,* J. Lloyd Stewart, University of Alabama; *First Vice-President,* W. C. Jones, Birmingham-Southern College; *Second Vice-President,* J. F. Duggar, Alabama Polytechnic Institute; *Secretary-Treasurer,* J. R. Sampey, Howard College.

THE following have been elected officers of the British Institution of Electrical Engineers for the year 1926–27: *President,* Dr. W. H. Eccles; *Vice-*

President, Colonel T. F. Purves; *Honorary Treasurer,* Lieutenant-Colonel F. A. Cortez Leigh.

SENATOR G. FANO, professor of physiology at the University of Rome, has been elected president of the newly organized Italian Society of Experimental Biology.

EDGAR S. BLOOM, a vice-president of the American Telephone and Telegraph Company, was on August 6 elected president of the Western Electric Company, succeeding Charles G. Du Bois, who had been president for the past seven years and who continues with the company as chairman of the board of directors.

AT a recent meeting of the Royal College of Surgeons, London, under the presidency of Sir Berkeley Moynihan, Sir Anthony Bowlby, Sir D'Arcy Power and Mr. Sampson Handley were elected members of the executive committee of the Imperial Cancer Research Fund.

DR. ERNEST MARSDEN, assistant director of education in New Zealand, has been appointed permanent secretary of the new industrial and scientific research department that is being established as recommended by Sir Frank Heath, secretary of the British Department of Scientific and Industrial Research. Dr. Marsden was formerly a fellow of Manchester University and professor of physics at Victoria College, New Zealand University. The purpose of the department is to encourage research and organize the application of the results to primary and secondary industries.

PROFESSOR JOCELYN F. THORPE, professor of organic chemistry in the Imperial College of Science and Technology, South Kensington, has been appointed chairman of the British Explosives in Mines Research Committee, in succession to Sir Frederic L. Nathan, who has resigned. Mr. F. E. Smith, director of scientific research under the Admiralty, has been made an additional member of the committee.

THE retiring address of Professor G. D. Birkhoff, of Harvard University, as president of the American Mathematical Society to be read at the annual meeting in conjunction with the sessions of the American Association for the Advancement of Science will have as title: "A Mathematical Critique of Some Physical Theories."

DR. ALLEN JOHN SMITH, professor of pathology and comparative pathology at the University of Pennsylvania and a brother of Dr. Edgar Fahs Smith, formerly provost of the university, died on August 19, aged sixty-three years.

DR. FRED S. MANDLEBAUM, who organized the pathological laboratory at Mount Sinai Hospital, New York City, and who was pathologist of the hospital, died on August 7, aged fifty-nine years.

THE executive committee of the Alabama Academy of Science has given its approval of the affiliation of the academy with the American Association for the Advancement of Science. Dr. Wright A. Gardner will represent the academy on the council of the association.

COMMEMORATING the founding of the society in 1906, the twentieth anniversary convention of the Illuminating Engineering Society is to be held in Spring Lake, New Jersey, from September 7 to 10, with headquarters at the Essex and Sussex Hotel. A comprehensive program of papers has been arranged including subjects of scientific, commercial and practical interest. The twentieth anniversary of the founding of the society will be fittingly observed, an entire session depicting "Twenty Years of Lighting Progress" having been set aside for this purpose. Another outstanding feature of the program will be the Lighting Service Session, planned particularly for the illuminating engineers of the central-station industry, with the view to supplying them with the best and latest ideas in their field.

IN connection with the gift of $300,000 from the Daniel Guggenheim Fund for the Promotion of Aeronautics to the California Institute recently reported in SCIENCE, we are informed that the facilities of the Douglas Airplane Company in Santa Monica, with its large corps of engineers, will be added to those of the institute for both instructional and research purposes in the effort to make a center of the first importance in Southern California for the development of both the theoretical and practical phases of aeronautics. Dr. von Karman, of Aachen, Germany, one of the foremost mathematical physicists and outstanding aeronautical engineers of Europe, has accepted the invitation of the Daniel Guggenheim Fund to visit the aeronautical centers of this country in the near future. He will go immediately to Pasadena for the sake of advising with the aeronautical staff of the institute, both as to the best type of aeronautical installation and as to the design of new planes already being perfected there.

HUGH BANCROFT, of Cohasset, has deeded to the Federation of the Bird Clubs of New England twelve acres of land for a bird sanctuary at Cohasset, to be known as the Bancroft Wild Life Reservation. This is the eleventh bird sanctuary secured by the Federation of the Bird Clubs of New England, by gift, purchase or by legislation.

PROFESSOR WILLIAM JAMES LEWIS, F.R.S., professor of mineralogy at the University of Cambridge and senior fellow of Oriel College, Oxford, who died

on April 16, aged seventy-nine years, bequeathed to the Mineralogical Museum, Cambridge, such of his books and scientific apparatus as his successor, or the demonstrator for the time being, may select; the balance to be offered to Bedford College for Women, London, to select such books as may be useful to the students.

WE learn from *Nature* that in order to commemorate the great services made to polar exploration by the late Dr. W. S. Bruce, leader of the Scottish National Antarctic Expedition, a fund has been raised by subscription, the proceeds of which will be awarded biennially "for some notable contribution to natural science, such as to zoology, botany, geology, meteorology, oceanography and geography, the contribution to be in the nature of new knowledge, the outcome of a personal visit to the polar regions on the part of the recipient." The award will consist of a medal, inscribed "Exploration of Polar Regions" and on the reverse "For Valuable Services," modelled on that designed by Dr. Bruce to commemorate the return of the *Scotia*, with in addition a sum of money. In the making of the award, preference will be given, other things being equal, to an explorer of Scottish birth or origin, and to one at the outset of his career as an investigator. The Royal Society of Edinburgh has been asked by the subscribers to accept and has accepted custody of the Bruce Memorial Fund, and awards will be made by a joint committee representing that society, the Royal Physical Society and the Royal Scottish Geographical Society. The first award will be made in 1926.

UNIVERSITY AND EDUCATIONAL NOTES

BY the will of the late Dr. J. William White, formerly John Rhea Barton professor of surgery in the University of Pennsylvania, the university receives a bequest of $150,000, the income of which is to be devoted to a chair of research surgery. The incumbent, when appointed, will be attached to the surgical staff with clinical facilities in the University Hospital.

BY the will of Mrs. Gertrude Baldwin Woods, wife of Dr. James Haughton Woods, professor of philosophy at Harvard University, $20,000 is left to establish the James H. Woods fellowship in philosophy at Harvard University, and $25,000 is left to Oberlin College to establish a Baldwin lectureship pertaining to art.

DR. RICHARD B. MOORE, of the University of Cincinnati, formerly chief chemist of the U. S. Bureau of Mines, has been appointed dean of the school of science of Purdue University.

DR. H. W. MANTER, assistant professor in the department of zoology of the Louisiana State University, has resigned to accept a position at the University of Nebraska. The vacancy created by the resignation of Dr. Manter has been filled by the appointment of Dr. Roy L. Mayhew, of Des Moines University, Iowa.

DR. A. M. HJORT, of the Research Laboratories of Parke, Davis Company, Detroit, has been appointed a professor of pharmacology on the faculty of the Dartmouth Medical School.

DR. FRITZ PANETH, professor of inorganic chemistry in the University of Berlin, will give a series of lectures on radioactivity at Cornell University during the coming academic year.

DR. NORMAN E. WOLDMAN, formerly research engineer for the American Bosch Magneto Corporation, Springfield, Mass., is now assistant professor of chemistry and metallurgy at the Postgraduate School of the Naval Academy at Annapolis, Md.

DR. E. A. SPESSARD, instructor in biology at the Harrison Technical High School, Chicago, Ill., has been elected professor of botany and head of the department of biology at Ouachita College, Arkadelphia, Arkansas.

E. B. VERNEY, who has for the last four years held a Beit Memorial Fellowship, has been appointed professor of pharmacology in University College, London.

AT the University of Cambridge, Mr. T. C. Hodson has been appointed reader in ethnology in succession to Dr. A. C. Haddon.

DISCUSSION

WAS PAUL GULDIN A PLAGIARIST?

STUDENTS of engineering and pure mathematics usually become familiar with the name of Guldin during their college days as a result of the very useful so-called Guldin's theorem, which states, among other things, that the volume generated by a plane figure rotated about a straight line is equal to the product of its area and the length of the circumference of the circle described by its center of gravity. In view of this familiarity it is naturally of unusual interest to such students to find statements in various places which reflect discredit on Guldin's integrity. One of the most forceful statements along this line appears on page 433, volume 1, of the recent "History of Mathematics," by D. E. Smith, and reads as follows:

> Two other Swiss mathematicians of the 17th century deserve mention,—one a genius, the other a plagiarist. The genius was Jobst Bürgi. . . . The other Swiss writer

was of a different character. He was a professor while Bürgi was a watchmaker; his name has been known for three centuries, while Bürgi's has been almost forgotten; but he was a plagiarist, while Bürgi was a genius. Paul Guldin began his work as a goldsmith.

While a university professor of mathematics could not be justified for trying to prove that all the earlier successful workers in his field were men of excellent character it is interesting to note that well-known mathematical historians have recently succeeded in showing that at least some of these workers have been accused severely without sufficient evidence. The Italian historian, G. Loria, recently called attention to the fact that the reputation of his countryman, H. Cardan, has suffered unduly, and J. Tropfke expressed the opinion that Paul Guldin did not know that the fundamental theorem which bears his name, and which he used extensively, is found in a somewhat vague form in the works of the well-known Greek mathematician Pappus, who is supposed to have lived at the close of the third century of the present era, "Geschichte der Elementar-Mathematik," volume 7 (1924), page 41. As the fact that Guldin failed to give credit for this theorem is the sole ground for calling him a plagiarist and as other well-known mathematical historians have recently expressed the same view as Tropfke, it seems probable that one more noted mathematician is being exonerated from a very unfortunate stain, and hence those who are inclined to support the view that the study of mathematics has a decidedly wholesome moral effect on its devotees find that one more serious historical obstacle to this view has fortunately been removed by a more careful consideration of the evidence upon which the harsh judgment was based.

The case against Guldin is weakened not only by the fact that Pappus failed to state the theorem in question in its clear modern form but also by the fact that various other writers who lived at about the same time as Guldin seem to have made the same mistake as he made, notwithstanding the established fact that the work of Pappus in which this theorem appears was then receiving considerable attention. Among these writers is the noted astronomer Kepler, who gave examples which seem to imply that he knew this theorem. The fact that he failed to state it explicitly is explained by the custom of many early writers to give illustrative examples of a fundamental principle without stating it explicitly. This custom is seldom followed in modern scientific publications, but it has the obvious advantage of leading the thoughtful readers to make far-reaching discoveries for themselves and to formulate for their own use inspiring general theorems. According to the modern custom the reader is usually expected to supply only details. The quotation noted above is a somewhat extreme instance of expressing conclusions for the reader instead of presenting the evidence and allowing him to draw his own conclusions. It is probable that many readers question the propriety of calling Bürgi a genius in a mathematical history in view of the elementary character of his contributions.

The world owes a great debt of gratitude to those who, like Cardan and Guldin, contributed powerfully towards the enlightenment of the human race, especially at a time when so few people took an active interest in scientific matters. It seems therefore to be very fitting that wide currency should be extended to results which tend to remove from their names unjust defamatory associations due to carelessness on the part of earlier writers. Personal shortcomings on the part of eminent contributors to the advancement of science have doubtless been magnified in many instances, and some of these magnifications are practically harmless, but before such severe personal criticisms, as some of those relating to Cardan and Guldin, are repeated the evidences upon which they rest should be carefully re-examined. Fortunately, this is being done now by various writers and it tends, in particular, to increase our sympathetic interest in Guldin in view of the unjust treatment which he seems to have received for a long time on the part of many writers. The present evidence tends to show that he was not a plagiarist.

G. A. MILLER
UNIVERSITY OF ILLINOIS

THE above criticism, expressed in some eight hundred words, may be set forth more clearly as follows: "Guldin's Law was original with him because Tropfke says so."

The added statement that "other well-known mathematical historians have recently expressed the same view" illustrates Professor Miller's habit of making general assertions without adducing any proof. It is an unfortunate habit and is probably one reason why his book reviews command so little attention. Doubtless another reason lies in the fact that he always seeks to show that every book is bad, that no author is a scholar, that no one is a master of style and that no historian goes to the sources. He illustrates the type of those who, as a French critic has expressed it, failing to succeed themselves, rail at those who "arrive."

Professor Miller, apparently desiring to strengthen his position, asserts that "Pappus failed to state the theorem in question in its clear modern form." Heath's rendering of Pappus is as follows: "Figures generated by a complete revolution of a plane figure about an axis are in a ratio compounded (1) of the

ratio of the areas of the figures, and (2) of the ratio of the straight lines similarly drawn to the axes of rotation from the respective centres of gravity." This certainly does not seem to lack clearness any more than does Guldin's "quantitas rotunda in viam rotationis ducta producit Potestatem Rotundam uno grado altiorem Potestate sive Quantitate Rotata."

The essence of Guldin's Theorem appears in the works of Pappus. These were published in 1588, 1589 and 1602, a generation or so before Guldin published (1641) his *Centrobaryca*, in which his version appeared (Lib. II, cap. VIII, 3). They were well known to scholars of that time as constituting the most important geometric work of the late Greek period. That a man like Guldin should have failed to know this important statement in such a well-known work is quite inconceivable.

As a bit of *obiter dicta* Professor Miller expresses his doubt about Bürgi's being a genius. Perhaps he was not; but in that case the critic would, of course, hold the same opinion as to Napier. Opinions differ.

Speaking of Professor Miller's reviews in general, the present writer does not believe that his method and purpose of book reviewing are worthy. He feels that a reviewer should set forth clearly and succinctly a statement of the purpose of a book, of the way in which this purpose has been developed, of the scholarship shown by the writer, of the style in which the work is written and of the kind of help that is given and the kind of readers who will find it of value. On the other hand, he should point out evidences of poor scholarship, of poor arrangement of material and of poor style, provided these are significant. The late Dr. Enestrom did this admirably with respect to historical errors, and his criticisms, based upon the actual sources and expressed without any evidence of self-aggrandizement, have been of the greatest value. Unfortunately he left no successor.

A work with such a large number of items as the one from which Professor Miller quotes is certain to have numerous statements in the first edition that require modification. In the case of this work the changes will be made in the second impression. They will not, however, include any modification in the statement referred to by him.

DAVID EUGENE SMITH

CRYSTALLINE TETRAMETHYL MANNOSE

IN this laboratory a study of the action of dilute alkali on tetramethyl sugars is being made, with a view to determining the probable mechanism of the Lobry de Bruyn interconversion of simple sugars under the action of dilute alkali. In the course of this investigation it was found necessary to prepare a large amount of tetramethyl mannose, heretofore known only as a syrup. This was made by methylation of alpha methyl mannoside with dimethyl sulphate and sodium hydroxide and subsequent hydrolysis with hydrochloric acid. Purification by distillation in large quantity was found unsatisfactory and extraction with low-boiling petroleum ether was tried. This resulted in the formation of crystalline tetramethyl mannose. The sugar comes out of petroleum ether in transparent massive crystals, apparently of the monoclinic system. The downward mutarotation in water from a specific rotation of +7.4° to +2.4° indicates that the crystals are of the alpha form.

Oxidation with bromine gave a syrupy tetramethyl mannonolactone whose specific rotation in water changed from +136.4° (init.) to +62.8° (final).

Preliminary study of the action of dilute alkali on crystalline tetramethyl mannose indicates a partial conversion into tetramethyl glucose. Further investigation of this reaction and of the crystallography of the compound is now in progress.

W. LEE LEWIS,
RICHARD D. GREENE
NORTHWESTERN UNIVERSITY,
EVANSTON, ILL.,
JUNE 6, 1926.

ZOOLOGICAL NOMENCLATURE

THE secretary of the International Commission on Zoological Nomenclature has the honor to invite attention of the zoological profession to the fact that application has been made to the commission to suspend the rules in the case of *Sarcoptes* Latr., 1804, tsd. (Latr., 1810) *passerinus*, and to place *Sarcoptes*, 1804, in the Official List of Generic Names with *S. scabiei* as type.

The argument states that the application of the rules to this "transfer" case will result in greater confusion than uniformity, involving generic, subfamily and family names, and designation of diseases in human and comparative medicine. The suspension requested will result in validating internationally accepted (though erroneous) nomenclature in consistent use for more than a century in zoology, and in human and comparative medicine.

The secretary is familiar with the premises and in his report to the commission will state that he considers this a typical case in which suspension is justified. He will, however, delay announcement of final vote until about October 1, 1927, in order to give ample opportunity to interested persons to express their views for or against the suspension.

C. W. STILES
Secretary to Commission
HYGIENIC LABORATORY,
WASHINGTON, D. C.
AUGUST 3, 1926

ROBERT SIMPSON WOODWARD

BIOGRAPHICAL material in regard to the career of R. S. Woodward is being compiled, and the undersigned would be grateful for any data which the readers of SCIENCE can furnish.

K. W. WOODWARD

UNIVERSITY OF
NEW HAMPSHIRE,
DURHAM, N. H.

QUOTATIONS

TWO ASTRONOMICAL AUTHORITIES ON THE WANING OF PURE SCIENCE RESEARCH IN THE UNITED STATES[1]

Two of the world's recognized astronomical authorities, Henry S. Pritchett, of New York, and George E. Hale, of Pasadena, California, view as dangerous the limited opportunities for pure science research in the United States.

Fearing that fundamental scientific investigation in this country is waning, these two notables are participating in a national project to promote and encourage research in the field of natural science. Associated with them are representatives of other important scientific fields, financiers, diplomats, lawyers and philanthropists. This group of twenty-six men were appointed by the National Academy of Sciences to raise a fund of $20,000,000 for research in pure science. Herbert Hoover is chairman of the undertaking and is devoting much personal attention to the successful realization of the project.

In his strictly academic days as a college professor and as president of the Carnegie Foundation for the Advancement of Teaching, President Pritchett has had ample opportunity to observe the crying need for funds to aid pure science investigators; to supply them with teaching assistance, with laboratory equipment and other necessities to carry on their work.

"It is a fact," President Pritchett says, "that the number of men who are competent to conduct scientific research of the highest order is limited. In order that research may be fruitful the problem which is being attacked must be significant and the man who engages in it must be a man of real ability. The presence in scientific research of men of the first order is indispensable to genuine progress. Whenever such men shall cease to appear amongst them who are devoted to research, the movement will lose its force."

Few men are more ably qualified to express an opinion on the value of pure science investigation and its need of financial support than Professor Hale, who during his seventeen years as director of the Mt. Wilson Observatory of the Carnegie Institute [*sic*] and as its organizer, has had ample opportunity to observe the disastrous drawback to progress, which frequently result [*sic*] from lack of funds to complete an investigation.

Professor Hale's own contributions to fundamental science, described in many of his important works, such as "The Study of Stellar Evolution," "Ten Years Work of a Mountain Observatory" and "The New Heavens," are among the most notable of the present day. The National Research Endowment is fortunate in being able to include among their board of trustees such particularly well-qualified authorities in the scientific world as Professors Pritchett and Hale.

The plan of administration will be to determine who among the ablest and most productive investigators, engaged in effective research in pure science, are in need of assistance. They will be asked to present their plans of research to the trustees of the fund, stating their exact needs, such as more time for research; the aid of scientific assistants; computers or technicians as well as the special instruments or accessories which may be needed. Appropriations will be made to them for a fixed period of years, subject to renewal if circumstances warrant it.

[1] Sent for publication in SCIENCE from the National Academy of Sciences, B and 21st Streets, Washington, D. C.

SCIENTIFIC BOOKS

The Biology of the Protozoa. By GARY N. CALKINS. Lea and Febiger, Philadelphia and New York, 1926, 623 pp. $7.50.

A NOTABLE work, "founded on thirty years of research on the Protozoa and on an equal number of years of teaching Protozoology" and worthy of such a foundation; a work of great value to students of Protozoa and to every one interested in the general problems of biology. Outstanding is the successful attempt to bring unity into the usually disconnected treatment of this heterogeneous group, through centering the whole about the general concepts of organization and vitality—particularly the latter. A book results that is consecutively readable, as well as valuable for reference.

There are detailed chapters, with illustrations (many original) on structural features and nuclei; on general physiology and reproductive processes; on the special morphology and taxonomy of the main groups of Protozoa. In these latter chapters are keys to genera, for the Mastigophora, Rhizopoda and Infusoria. The treatment is up to date and is throughout informed by the results of the author's own investigations.

Of special interest are the three chapters on "Vitality"; on "Phenomena accompanying Fertilization" and on "Effects of Reorganization and the Origin of Variations in the Protozoa." It is in these fields that the author has made his most notable contributions, and about concepts derived from these the entire book is centered. Further, these are the subjects that are of most general biological interest, and on which there has been most discussion and divergence of conclusion: potential immortality, senescence, rejuvenescence, the causes of decline and death. Calkins had early made his own the doctrine that the organism becomes old, "deteriorates, uses itself up, simply by prolonged exercise of its functions" (Maupas); that "the life process contains within itself the germ of death" (Hertwig) and that conjugation remedies this deterioration; produces rejuvenescence. In opposition to Maupas, Calkins held that after decline had occurred, vitality is brought by conjugation back to a high level, so that life runs in cycles, beginning at a high potential and gradually running down, until either death or conjugation occurs; the latter restores the vitality to a high level, whence again it runs down. As a measure of vitality the rate of fission is employed; this plotted shows a curve steadily descending to death or conjugation.

But the validity of this doctrine was gradually shaken. Through the work of Enriques, Woodruff, Metalnikoff and others, the necessity for this decline became doubtful; by them it was attributed, not to processes necessarily bound up with living, but to certain environmental inadequacies. When the latter were remedied, infusoria lived indefinitely, not running down, even though conjugation did not occur. The rejuvenating effect of conjugation was therefore brought strongly into question and direct evidence given, by the reviewer and others, that it is nonexistent.

But the balance was soon restored. Calkins triumphantly unearthed in Uroleptus an ideal exemplar for all the postulates of his doctrine; it regularly declines in fission rate, and conjugation restores the reproductive power. Woodruff with Spathidium confirmed this. Calkins therefore holds in the present work to his point of view.

Yet the significance of the whole was much changed by Woodruff and Erdmann's discovery of endomixis, a process in which the physiologically active macronucleus is replaced from the micronucleus (as in conjugation) but without amphimixis, or the union of two individuals or two nuclei. Endomixis restores the waning vitality as does conjugation. Calkins therefore admits that "Woodruff is quite right in stating that amphimixis is unnecessary for continued life of a ciliate" (p. 545). What is the function of amphimixis? The truth that it is "a means of inaugurating variations is undeniable" (p. 553); but Calkins still inclines to hold that it "arose in connection with some fundamental protoplasmic need," and hankers for the doctrine that this need is "a result of vital activities and changes in organization which render them (the organisms) unable to continue metabolic activities without fusion" (p. 553). And yet on an earlier page he has set forth that amphimixis is unnecessary for continued life, even in organisms in which it occurs; and that there are large groups of Protozoa in which there is no evidence of its occurrence. There are other respects also in which the presentation reflects the present unsettled state of knowledge. Calkins's "fundamental thesis" is "that continued metabolism leads to functional weakening and ultimate cessation of vitality" (p. 552). Woodruff, Enriques and many others hold that such weakening is avoidable, and due, where it occurs, to faulty metabolism resulting from environmental conditions not adapted to the organism. Calkins agrees that supplying certain environmental conditions may remedy the weakening; "individuals might thus be 'doctored' at intervals with a resulting repression of cumulative differentiations and a corresponding maintenance of youth" (p. 478). The diversity of view on this matter, so far as possible experimental detection of differences is concerned, is whittling down to an extremely fine point.

On other questions, as on these, the discussion inclines to a conservatism that is undogmatic and at times wavering; with full presentation of opposing points of view. The book will serve, not only as a compendium of the significant knowledge on Protozoa, but as an excellent guide to the present situation in many fundamental problems of biology.

H. S. JENNINGS

The Elements of Physics and Chemistry. By VERNON BOSMAN. Pp. XI, 295; Juta & Co., Ltd. Cape Town; Johannesburg.

SEVENTY to one hundred years ago it was customary to begin text-books of chemistry with a presentation of the more important laws of physics. At the present time the fields of chemistry and physics overlap at so many points that several of the most important advances in chemical science have been contributed by men who were trained primarily as physicists. This is so true that it is scarcely profitable to ask of some topics whether they belong to physics or chemistry. The book we have before us is intended to supply the necessary information and training for students to meet the requirements of the matriculation examinations in South Africa.

The portion of the book on physics confines itself

to the elementary laws of density, statics and dynamics, heat, calorimetry and the properties of liquids, gases and vapors. The chemical portion includes the fundamentals of the atomic and molecular theories and information about hydrogen, oxygen, chlorine, nitrogen, sulfur and carbon. Each part includes a considerable number of problems and the whole should furnish an excellent basis for the further study of the subjects in a college or university.

It is well worth while for American educators to consider whether a year in the high school given to the study of the two subjects would not be better than a year devoted exclusively to one or the other. Certainly every high school student should have as good a knowledge of both subjects as can be acquired from this book.

W. A. NOYES

SCIENTIFIC APPARATUS AND LABORATORY METHODS

OPTIMUM CONDITIONS FOR MUSIC IN ROOMS

MUSICIANS complain that rooms are usually ruined for music if they are adjusted by sound-absorbing materials to give "perfect" acoustics. On the other hand, rooms left reverberant so that musicians find it "easy" to play and to sing are quite objectionable for satisfactory listening.

This apparent contradiction has puzzled the writer for a number of years, so that recently a series of experiments was conducted to discover the facts, if possible. One experiment consisted in having musicians play first in a very "dead" room, and then later as the reverberation was progressively increased by removing portions of sound-absorbing material. At first it was "hard to play" in the room, but it became easier as the reverberation increased, until finally the notes "ran together" and several instruments could hardly be played in proper time in concert because of the overlapping sounds; but it was still easier to play than before. At the same time, listeners in the room found the conditions worse and worse as the reverberation increased. An experiment conducted in the reverse order, with the room very reverberant at first and then made successively deader, led to the same conclusions.

Further experiments were conducted in other rooms, the volumes varying from about twelve thousand to two hundred thousand cubic feet, and it was again found that musicians found reverberant conditions satisfactory for playing, but that listeners heard better in portions of halls that were deadened.

A crucial experiment was then devised in which a small studio was adjusted by sound-absorbing materials to give "perfect" conditions for listening in accordance with optimum data.[1] Expert musicians forming a string quartet were interested to assist in the experiment and play in the room. Their comment was immediately adverse. Some of the sound-absorbing material near them was then moved to the far end of the room and the playing resumed. The conditions for playing were "better," and listeners in the room decided the music sounded better. More material was moved in the same manner with greater improvement. Finally all the material about the musicians was transferred to the other end of the room. The room was then regarded as quite perfect for both playing and listening.

This simple experiment makes it clear why deadening a room in the usual manner ruins it for music. Musicians find it hard to play if surrounded by sound-absorbing materials, and the resultant music is not acceptable for listeners, so that the effect is unsatisfactory to all. By shifting the sound absorbents to one end of the room, a reverberant space is left for the easy generation of music—the musicians find free expression for the finer details of compositions and the listeners are doubly fortunate in having good music to listen to and in having a deadened surrounding which makes listening enjoyable. In other words, the conditions in the same room must be quite different for playing and listening. The time of reverberation was found to be the same in all parts of the room, but the intensity of sound was much greater near the musicians than in the deadened end of the room.

The results of this experiment should find application in many halls that are now unsatisfactory in acoustic effect. For instance, in a concert hall, the stage should be left quite reverberant, but the audience section should be deadened in accordance with the optimum data already mentioned.

One concert that was puzzling to the writer is now easily explained. In a large auditorium at the university, a piano concert was given by Paderewski. Preliminary calculations indicated that "perfect" conditions would obtain if six thousand seven hundred auditors were present, because of the absorption of sound by the clothing worn. Actually five thousand five hundred people attended, yet Paderewski stated the hall was "wonderful in its response," and the audience regarded the hearing conditions as "fine." What happened was that a considerable space was left vacant about the platform upon which the piano was placed, and this space together with nearby reverberant walls and ceiling gave acceptable conditions for playing. The audience was packed closely

[1] Wallace Sabine, "Collected Papers on Acoustics," page 76; F. R. Watson, "Acoustics of Buildings," page 30; S. Lifshitz, *Physical Review*, Vol. 27, page 618, 1926.